J Raptor Res. 33(2):117–122

EFFECTIVENESS OF CONSERVATION MEASURES ON MONTAGU'S HARRIERS IN AGRICULTURAL AREAS OF SPAIN

C. CORBACHO AND J.M. SÁNCHEZ
Grupo de Investigación en Conservación, Área de Biología Animal, Universidad de Extremadura, Avda. de Elvas s/n, 06071 Badajoz, Spain

A. SÁNCHEZ
Dirección General de Medio Ambiente, Junta de Extremadura, Edificio Múltiple, Mérida, Spain

ABSTRACT.—The breeding success of Montagu's Harrier (*Circus pygargus*) in farming areas of southwestern Spain was studied in a managed population vs. a controlled one. Conservation measures resulted in a decrease in nestling mortality rate, which in turn resulted in a higher breeding success in managed than in unmanaged pairs. However, the effectiveness of intervention at nest sites was constrained by laying date, brood age, clutch size, and type of crop where nesting took place. In very delayed clutches (with unhatched eggs or with broods younger than 10-d old at harvest time) total breeding failure was recorded. The impact of farming operations, mainly harvesting, depends largely on the degree of mismatch between the timing of fledging and harvesting. The type of crop selected as nesting habitat was also important, mainly because of variations in the timing of harvest of the respective crops. Southern populations of harriers appeared to be more influenced by farming operations than did northern ones because harvesting occurred earlier in southern locations. Therefore, conservation measures are of fundamental importance for the future of Montagu's Harrier populations, because Mediterranean areas provide nesting habitat to a large number of breeding pairs in the western Palearctic.

KEY WORDS: *Montagu's Harrier*; Circus pygargus; *Iberian Peninsula; agricultural environments; breeding success; conservation measures.*

Efectividad de las medidas de conservación de aguilucho cenizo en áreas agrícolas de España

RESUMEN.—Se estudió el éxito reproductivo del aguilucho cenizo (*Circus pygargus*) en áreas agrícolas del sur-oeste de la Península Ibérica, comparando una población manejada respecto a una controlada. Las medidas de conservación ocasionaron un descenso en la mortalidad de los pollos, lo que determinó un mayor éxito reproductivo en las parejas manejadas. Sin embargo, su efectividad estuvo limitada por la fenología reproductiva, la edad de las polladas, el tamaño de puesta, y el tipo de cultivo donde nidificaron. En puestas muy tardías (en estado de incubación, o con polladas menores de 10 días de edad en el momento de la cosecha) el fracaso reproductivo fue completo. Cuanto más temprana fue la cosecha en relación al ciclo reproductivo menor resultó el éxito reproductivo de las parejas. El tipo de cultivo seleccionado como hábitat de nidificación fue también un factor determinante, debido a las variaciones en las fechas de cosecha entre los mismos. Las poblaciones meridionales se hallan más influenciadas por el ciclo agrícola que las norteñas, ya que en las primeras la cosecha tiene lugar antes. Las medidas de conservación son por ello de vital importancia para el futuro de los aguiluchos cenizos, debido a que las regiones mediterráneas acogen buena parte de la población reproductivo de la especie en el Paleártico occidental.

[Traducción de César Márquez]

Montagu's Harriers (*Circus pygargus*) have a widespread but scattered distribution in the Palearctic. The species has suffered a decline in recent decades due to the loss of native habitats to agriculture and forest developments (Cramp and Simmons 1980, Tucker and Heath 1994). As a result, Montagu's Harriers have increasingly begun to use farming areas where cereal crops are raised as their nesting habitat. Because the breeding season of harriers and the harvest season coincide, the increased use of mechanized farming practices has greatly decreased the breeding success of harriers in these areas (Pérez-Chiscano and Fernández-Cruz 1971, Berthemy et al. 1983, Castaño 1995,

Corbacho et al. 1997). Mediterranean populations of Montagu's Harrier seem to be highly dependent on conservation measures because of the high breeding failure rates that occur when these measures are absent (Corbacho et al. 1997). However, there have been no studies to analyze the factors constraining the effectiveness of management actions. The aim of this study was to evaluate the effectiveness of management actions on the breeding success of Montagu's Harriers.

STUDY AREA AND METHODS

The study was carried out from 1987–91 in Extremadura (southwestern Spain; see Corbacho et al. 1997), a region that provides refuge to one of the main populations of Montagu's Harriers in the western Palaearctic (Tucker and Heath 1994, Ferrero 1996). We monitored five breeding areas: two in La Serena and one each in Llanos de Cáceres, Cornalvo and Llanos de Badajoz-La Albuera. In all of these areas, nests were in cereal fields, with several pairs (2–10) nesting in the same plot (pseudocolonies, *sensu* Cramp and Simmons 1980). The study areas were in arable landscapes where land use was based on dry agricultural practices, with wheat, oats, and barley predominating along with vine, olive, sunflower, and small patches of holm-oak dehesas. Shrubsteppe habitats were also represented in both Llanos de Cáceres and La Serena. The study areas had a typical Mediterranean climate with mean annual precipitation ranging from 400–600 mm, distributed primarily from November–April, and mean annual temperature ranging from 14–17°C. During the breeding period, mean temperature and rainfall ranged from 13.5–15.0°C and 10–96 mm in April to 24–29°C and 0–50 mm in July. No statistical differences in any of the climatic variables (Kruskal-Wallis test, $P > 0.05$ in all cases).

A total of 108 nests was studied (26 in 1987, 12 in 1988, 18 in 1989, 39 in 1990, and 13 in 1991). The Cornalvo area had 69 nests, with the remainder located in La Serena (18), Llanos de Badajoz-La Albuera (17), and Llanos de Cáceres (4), respectively. All nests were in cereal crops: 67 (63%) in barley, 23 (21%) in wheat, 9 (8%) in oats, and 9 (8%) in mixed barley-oat crops. Harrier colonies were monitored regularly (once a week) from the beginning of the breeding cycle (early April); visits increased (every 3–4 d) during the nestling period (15 May–10 July). During the first visit, 88% of nests ($N = 95$) were in the incubation period, with the remainder ($N = 13$) in the nestling stage. Each breeding season, all the nests in some colonies were treated as controls ($N = 36$) and no conservation measures were applied to these nests. At the other nests ($N = 72$), management measures included the removal of young (or eggs) from nests prior to harvesting and baling, and their subsequent return to the nest after harvesting. It took <1 hr to remove eggs and young and return them to nests in all cases so artificial incubation and nursing of young were not necessary. There were no differences in laying date or clutch size between managed and unmanaged clutches (Mann-Whitney U test, $P = 0.64$ and $P = 0.26$).

In order to assess seasonal patterns in breeding performance, laying dates were classified in 10-d periods starting from 11 April (all years pooled), resulting in five phenological classes in relation to the onset of egg laying (Class 1: 11–20 April, 6 clutches; Class 2: 21–30 April, 20, Class 3: 1–10 May, 26; Class 4: 11–20 May, 10; and Class 5: >20 May, 10). For Montagu's Harrier, harvesting appears to be the main determinant of breeding success in arable farmland such as that in the study area (Corbacho et al. 1997). Hence, we classified clutches according to their breeding stage at harvesting time; this resulted in pairs at incubation stage ($N = 13$), pairs at nestling stage (rearing young, $N = 65$), and pairs with fledgings ($N = 12$). At the same time, we separated nestling pairs according to the age of broods at harvest time: early age (1–10 d, $N = 11$), middle age (11–20 d, $N = 26$) and late age (>20 d, $N = 16$). Analysis of reproductive output were performed using: hatching success as the number of eggs that hatched versus the number of eggs laid, including clutches deserted or preyed upon; nestling mortality rate (% of young that died versus the number hatched); proportion of successful pairs (the number of pairs with at least one nestling fledged versus total number of pairs that laid eggs); and breeding success (the mean number of fledglings per laying pair). Results are shown as arithmetic mean ± standard deviation or %, with sample size indicated in each case. Nonparametric methods and two-way analysis of variance with interaction was used to test for differences (Zar 1996), with the exact method used in each case indicated.

RESULTS

We found the reproductive success of Montagu's Harriers to be strongly dependent on management measures undertaken at harvest time. They resulted in an important decrease in nestling mortality rate (28% in managed pairs vs. 67% in control ones; G-test, $P < 0.001$; $N_1 = 55$, $N_2 = 18$) which in turn resulted in a higher proportion of successful pairs (75% vs. 29%; G-test, $P < 0.001$) as well as breeding success (2.04 ± 1.53 vs. 0.77 ± 1.28; Mann-Whitney U test, $P = 0.001$) in managed ($N = 68$) than in unmanaged ($N = 34$) pairs.

A two-way Anova showed that breeding success was highly dependent on both laying date ($F_{4,56} = 4.45$, $P = 0.003$) and management performed ($F_{1,56} = 8.51$, $P = 0.005$) (Fig. 1). Hatching success, which was unaffected by management actions, showed a large seasonal decline (Spearman rank correlation test, $r_s = -0.57$, $P < 0.001$, $N = 59$, all data pooled). Nestling mortality rate increased as the laying date was increased in unmanaged broods ($r_s = 0.69$, $P = 0.009$, $N = 14$), and high mortality was recorded in late broods (80% in Class 3, 100% in Classes 4 and 5). However, this attribute showed no significant seasonal increase in managed clutches (17% in Class 1, 58% in Class 2,

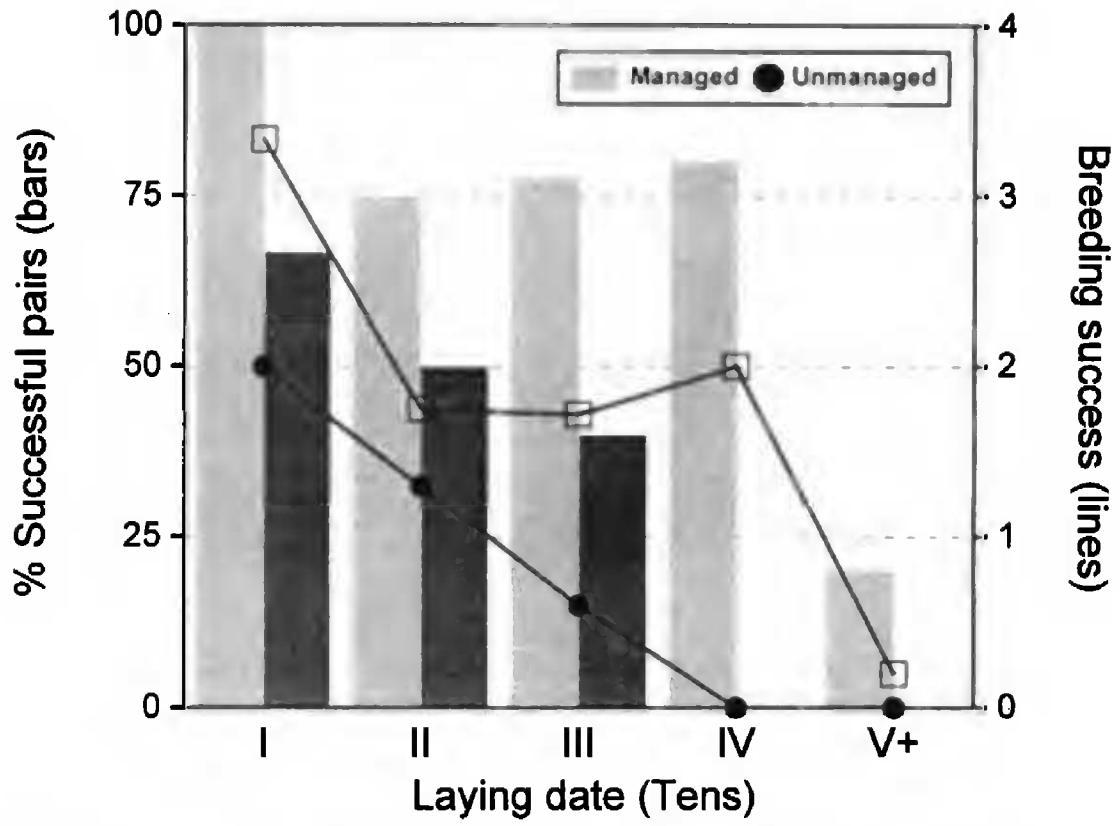

Figure 1. Variation in the percent successful pairs and breeding success of Montagu's Harriers in agricultural areas of southwestern Spain according to laying date and management measures undertaken. Laying date categories were determined as follows: day 1 = 10 April; I = 1–10; II = 11–20; III = 21–30; IV = 31–40; V = >40 days after 10 April.

41% in Class 3, 33% in Class 4, and 50% in Class 5; $r_s = 0.16$, $P = 0.40$, $N = 30$). As a result, managed clutches had a high proportion of successful pairs as well as breeding success; these values were maintained until well into the breeding season (Fig. 1). In contrast, unmanaged pairs showed high breeding failure, because only early clutches (Classes 1 and 2) had good reproductive output (Fig. 1). However, the effect of laying date was not linear, even in the absence of management. This was due to the variations in timing of farming activities (especially the harvest) either between localities or from one year to another. The different crops selected as nesting habitats in any one year or locality were also involved for the same reason.

It was better to relate reproductive output to the breeding stage of each pair at harvest time than to relate it to laying date. In our study, all pairs at incubation stage during harvesting ($N = 13$) failed because of total hatching failure. In contrast, all pairs that raised young before harvest (pairs that fledged young) showed a high breeding success both in managed (3.14 ± 0.69, $N = 7$) and unmanaged clutches (3.00 ± 0.00, $N = 5$). Two-way Anova (breeding stage-management) showed that the stage at harvest time was the only factor determining significant differences in breeding success ($F_{2,71} = 20.62$, $P < 0.001$). Therefore, breeding stage at this critical moment appeared to be the main factor affecting reproductive output. In this sense, conservation measures were clearly effective at the nestling stage. First, management actions greatly increased survival of young (30 to 63%; G-test, $P < 0.001$, $N_1 = 11$, $N_2 = 37$), which in turn resulted in a higher proportion of successful pairs (82% vs. 47%; G-test, $P < 0.004$, $N_1 = 39$, $N_2 = 13$) and breeding success (2.08 ± 1.40, $N = 39$ vs. 1.16 ± 1.34, $N = 19$; Mann-Whitney U test, $P = 0.007$) in managed versus unmanaged pairs. Second, managed pairs at nestling stage had a reproductive success for both attributes that was similar to that of pairs at fledging stage (G-test, $P = 0.09$, and Mann-Whitney U test, $P = 0.30$, respectively).

The older the broods were, the greater the breeding success for both managed (Spearman rank correlation test; $r_s = 0.84$, $P = 0.001$, $N = 14$) and unmanaged broods ($r_s = 0.68$; $P = 0.002$; $N = 19$). Pairs with broods in the early-age group failed completely, while all pairs in the late-age group were successful, with high breeding success for both managed (2.60 ± 0.55, $N = 8$) and unmanaged (2.14 ± 0.93, $N = 8$) broods (Mann-Whitney U test, $P = 0.18$). Conservation measures appeared to be effective only for middle-age broods, which had higher scores in managed than in unmanaged pairs for both proportion of successful pairs (75%

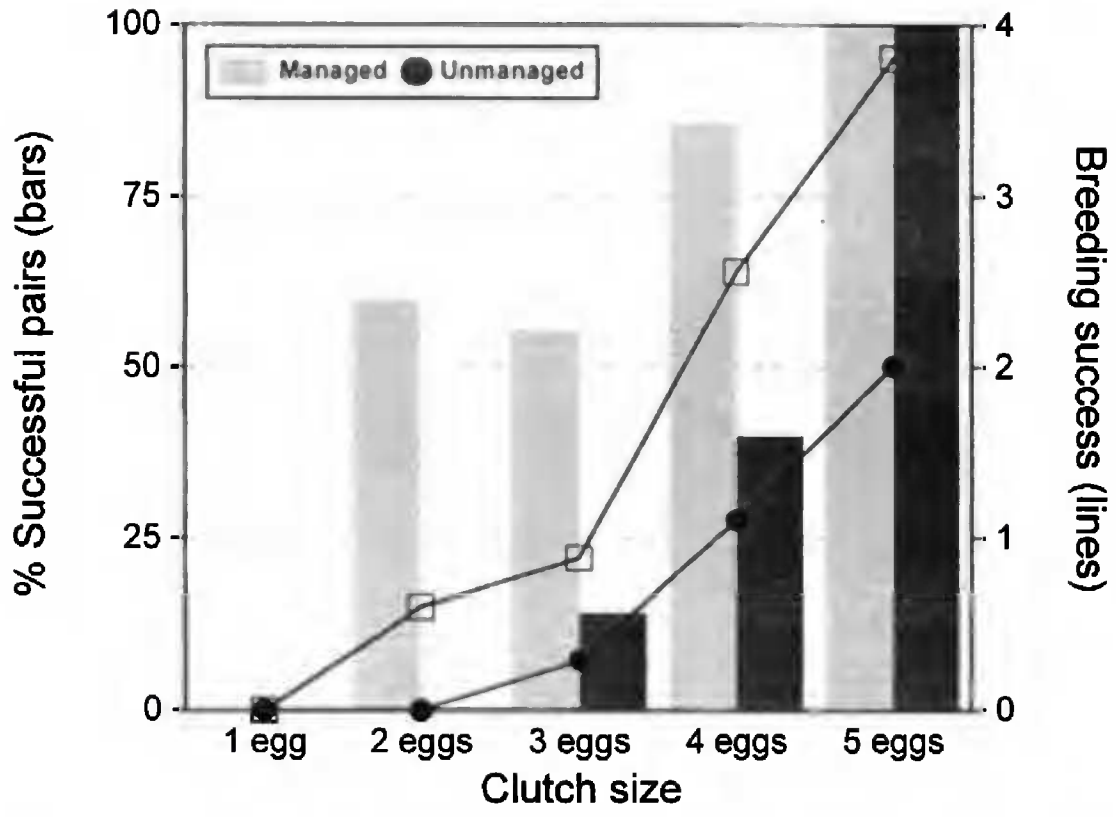

Figure 2. Variation in percent of successful pairs and breeding success of Montagu's Harrier in agricultural areas of southwestern Spain according to clutch size and management measures undertaken.

vs. 14%; *G*-test, $P < 0.001$) and breeding success (1.25 ± 0.96 vs. 0.29 ± 0.76, $N_1 = 16$ and $N_2 = 8$; Mann-Whitney *U* test, $P = 0.045$), respectively.

Nesting habitat selection affected the success of pairs, because of variations in timing of harvest among the different crops. No differences in mean harvesting date were found among wheat (14 June), oats (14 June), or mixed wheat-oats (12 June) (Kruskal-Wallis test, $P = 0.82$), and thus these data were pooled. However, the timing of harvest for barley (26 June) was significantly later than for the rest of the cereal crops (Mann-Whitney *U* test, $P < 0.001$), and this in turn affected the age of young at harvest time. The later the harvest occurred, the older were the broods (Spearman rank correlation, $r_s = -0.60$, $P < 0.001$, $N = 57$). Thus, in barley crops at harvest age of broods (24.31 ± 10.83, $N = 13$) was older than in both wheat and/or oat crops (15.16 ± 8.48, $N = 44$) (Mann-Whitney *U* test, $P = 0.008$). Similarly, the number of pairs with fledglings at harvest time in barley crops (35.4%) was higher than in the other crops (9.30%) (*G*-test, $P = 0.04$, df = 2). However, with respect to breeding success, the few data available (only two clutches) for unmanaged pairs nesting in barley crops made it impossible to test the influence of nesting habitat selection. In managed clutches, no differences in reproductive output were observed between pairs nesting in wheat-oats and barley crops with regard to breeding success (1.53 ± 1.46 vs. 1.88 ± 1.58; Mann-Whitney *U* test, $P = 0.48$) and proportion of successful pairs (66.67% vs. 70.59%; *G*-test, $P = 0.33$; $N_1 = 30$ and $N_2 = 17$ in both cases). This pointed out the effectiveness of conservation measures on the breeding of Montagu's Harriers in farmlands.

Breeding performance showed clear trends that depended on clutch size but these differences were independent of management measures performed. No seasonal decrease in clutch size was associated (Spearman rank correlation test, $P > 0.05$; Corbacho et al. 1997). The greater the number of eggs laid, the greater the hatching success (Spearman rank correlation; $r_s = 0.32$; $P = 0.002$; $N = 92$) that was realized. Clutches of 1, 2, and 3 eggs yielded a lower reproductive output for all variables in comparison to 4- and 5-egg clutches in both managed and unmanaged clutches (Fig. 2). Nevertheless, for a given clutch size, managed clutches resulted in a higher proportion of successful pairs and greater breeding success than unmanaged clutches (Fig. 2). Thus, both clutch size ($F_{4,82} = 9.31$, $P < 0.001$) and management actions ($F_{1,82} = 5.68$, $P = 0.019$) had decisive influences on breeding success.

DISCUSSION

Breeding success of Montagu's Harrier in Mediterranean areas, where breeding occurs chiefly in cereal crops, appears to be highly dependent on

conservation measures (Corbacho et al. 1997). We showed that the effectiveness of management actions had some constraints. Laying date was the main factor affecting it, by its influence on breeding stage and brood-age at harvest time. Thus, neither hatching success nor mortality rate of young increased with the use of conservation measures in very delayed clutches. This happened because of the helpless situation of clutches (eggs in unhatched clutches) or broods (young <10-d old) during and after harvesting as they became more vulnerable to predation and/or theft, or desertion by females. The longer the eggs and broods remained in a defenseless situation, the lower the reproductive success. On average, all pairs that delayed laying until after 15 May were unsuccessful, regardless of any management applied. However, breeding failure occurred in unmanaged clutches even when laying occurred in the beginning of May. Although this 15-d period may not be important, it occurs at a time when a considerable number of pairs start their clutches (33%, Corbacho et al. 1997).

A comparative analysis in the western Palearctic showed that although breeding season starts earlier in the Mediterranean area than in northern Europe (Schipper 1979, Corbacho et al. 1997), the timing of harvest in cereal crops in southern latitudes also occurs earlier. Consequently, the overlap of the breeding cycle with the postharvest period is greater in southern populations, with the result that the number of pairs that finish breeding before harvesting decreases southwards (10–40%, Berthemy et al. 1983; 70%, Pandolfi and Giacchini 1991; 40%, Arcà 1989; over 50%, Arroyo 1995; 18%, Castaño 1997; 16%, this study). In our study, the number of pairs affected by farming practices (either at incubation or brooding stages) varied from high (>80%) to complete (100%). The increasing use of early varieties of cereal crops may constitute a further threat to breeding harriers in arable lands.

Breeding condition of the pair may also play a role in determining reproductive output (Schipper 1979, Newton 1979), but in agricultural environments this factor is overshadowed by farming practices. If clutch size is an indicator of pair quality (Drent and Daan 1980), low quality breeders achieved a low reproductive output despite management (Corbacho et al. 1997, this study).

In conclusion, conservation measures offset the negative influence of intensified mechanization of farming practices on Montagu's Harrier nesting in cereal fields, with the result that breeding success of managed populations in agricultural environments of Mediterranean areas was similar to that of northern European breeders in natural habitats (Corbacho et al. 1997). However, predation and theft of young was more pronounced in managed (50%) than in unmanaged nests (30%), suggesting that management activities attract attention from predators and humans (Arcà 1989). Therefore, although cultivated areas in southern Europe seem to provide suitable habitat for the species, integral conservation measures are urgently needed, especially because that region provides refuge to one of the largest populations of Montagu's Harrier in the western Palearctic (Berthemy et al. 1983, Tucker and Heath 1994, Ferrero 1996). In addition to conventional conservation schemes (removal of young to increase survival), other actions such as delayed harvesting or setting sheltering areas around main colonies should be considered. Such actions could be accompanied by subsidies for farmers in order to compensate for any economic losses incurred. Environmental education programs should be carried out in the areas near the sites of the main colonies, because of the large number of nests that are unsuccessful because of theft and destruction at harvest time.

ACKNOWLEDGMENTS

A. López, A. Fernández, J.L. Pérez, P. Corbacho, and the Guard Service of Dirección General de Medio Ambiente of Junta de Extremadura assisted in field studies. We thank A. Muñoz del Viejo and two anonymous referees for useful comments on a earlier version of this manuscript. Thanks also to J. McCue and R. Morán for English translations.

LITERATURE CITED

ARCÀ, G. 1989. La conservazione dell'Albanella minore *Circus pygargus* nelle aree agricole della Maremma Tosco-Laziale. *Atti V^ol Conv. Ital. Ornitol.*, Rome, Italy.

ARROYO, B. 1995. Breeding ecology and nest dispersion of Montagu's Harrier in central Spain. Ph.D. dissertation. Oxford Univ., Oxford, U.K.

BERTHEMY, B., P. DABIN AND M. TERRASSE. 1983. Recensement et protection d'une espèce protégée: le Busard cendré. *Le Courier de la Nature* 83:10–16.

CASTAÑO, J.P. 1995. Efecto de la actividad de siega y causas de fracaso reproductivo en una población de aguilucho cenizo *Circus pygargus* L. en el SE de Ciudad Real. *Ardeola* 42:167–172.

———. 1997. Fenología de puesta y parámetros reproductivos en una población de aguilucho cenizo *Circus pygargus* en el Campo de Montiel. *Ardeola* 44:51–59.

CORBACHO, C., J.M. SÁNCHEZ AND A. SÁNCHEZ. 1997. Breeding biology of Montagu's Harriers (*Circus pygargus*) in agricultural environments of the southwestern Iberian Peninsula and comparison with other populations in the Western Palearctic. *Bird Study* 44:166–175.

CRAMP, S. AND K.E.L. SIMMONS. 1980. The birds of the western Palearctic. Vol. II. Oxford Univ. Press, Oxford, U.K.

DRENT, R.H. AND S. DAAN. 1980. The prudent parent: energetic adjustements in avian breeding. *Ardea* 68: 225–252.

FERRERO, J.J. 1996. La población ibérica del aguilucho cenizo *Circus pygargus*. *Alytes* 7:539–560.

NEWTON, I. 1979. Population ecology of raptors. T. & A.D. Poyser, London, U.K.

PANDOLFI, M. AND P. GIACCHINI. 1991. Distribuzzione e successo riproduttivo di Albanella minore, *Circus pygargus,* nelle Marche. *Riv. Ital. Ornitol.* 61:25–32.

PÉREZ-CHISCANO, J.L. AND M. FERNÁNDEZ-CRUZ. 1971. Sobre *Grus grus* y *Circus pygargus* en Extremadura. *Ardeola* (vol. esp.):509–574.

SCHIPPER, W.J.A. 1979. A comparison of breeding ecology in three European harriers (*Circus*). *Ardea* 66:77–102.

TUCKER, G.M. AND M.F. HEATH. 1994. Birds in Europe. Their conservation status. Bird Life Conservation Ser. No. 3. Bird Life International, Cambridge, U.K.

ZAR, J.H. 1996. Biostatistical analysis. 3rd Ed. Prentice Hall, Princeton, NJ U.S.A.

Received 29 December 1997; accepted 4 February 1999